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Water Rate Affordability and the Impacts of Combined Sewer Overflow Systems

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Lauren Schnoebelen

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Bonnie Keeler	13 June 2019	25 July 2019
Typed Name & Title, Paper Supervisor	Date, oral presentation	Date, paper completion
Greg Lindsey GREG LINDSEY		25 July 2019
Typed Name & Title, Second Committee Member		Date

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Abstract

The purpose of this research is to evaluate the links between water affordability and investments cities have made in developing combined sewer overflow systems. Customer affordability is a concern for residents as it affects household utility bills. Rates are also a concern for public water and wastewater utilities because it impacts how much revenue they receive within a given year. I analyzed three different high cost system indicators; the Environmental Protection Agency Residential Indicator, the Affordability Ratio, and the Minimum Wage Indicator. Two-sample t-tests were then run to identify if municipalities who have made investments in combined sewer overflow systems are more likely to be classified as high cost systems based on the three affordability indicators. I found that by using the alternative high cost Affordability Ratio and Minimum Wage indicators, six times as many cities were identified as having a high cost system when compared to those identified by the Residential Indicator. The two-sample t-tests for each indicator showed a significant correlation (p=0.05) between the presence of a combined sewer overflow and classification of a high-cost system. The information gained from this study helps to show that the current criteria for identifying high cost systems through the EPA have limitations. Bringing in more variables that address the concerns over low income households and looking at both annual and monthly water and wastewater bills can provide a more accurate picture on which cities quality as high cost systems.

Introduction

People use water on a daily basis for a variety of purposes, including drinking, bathing, and cleaning; yet being able to afford this water is a growing concern for many. It can be seen in recent publications, like U.S. Urban Water Prices: Cheaper When Drier (Luby et al, 2018) and Improving the Narrative on Affordability and the Measurements We Need to Take Us There (Mumm & Ciaccia, 2017), this topic about water affordability is something many are talking about and expressing concerns over. But when it comes to water affordability, attention needs to also be brought to the factors surrounding costs of infrastructure and treating wastewater to standards designated by the federal government. For a residential household, wastewater can include the used water from showering, cleaning, flushing, cooking and more in addition to anything else sent down a drain in a household. This wastewater is then transported through the underground pipe system of water infrastructure to the local treatment plant. To better understand these concerns for the cost of infrastructure and the interest forming around water affordability, it's good to start at the bill families receive each month.

Public water utilities typically charge families in a two-part water and wastewater bill; the first is a per unit rate which is based on the amount of water and wastewater a household uses while the other is a fixed fee that doesn't change and covers the costs of administrative fees, infrastructure fees and others which are unique to the local utility. According to the Environmental Protection Agency (EPA), a community's average cost of water and wastewater services within a municipality's district is measured as a percentage of the median household income within the city limits. If this value is greater than 4.0 or 4.5% for both water and wastewater services, the system is considered a high cost system and not affordable for families (USEPA, 1997). Having this designation of a high cost system impacts both customer affordability and other areas of a public utility, such as their access to additional financial resources.

Customer affordability is a concern for any utility because it impacts how much revenue they receive within a given year. This is due to customer bills covering the utility's operating costs and helping with payments towards any existing loans (Metropolitan Council, 2019). The size of the customer base and the per unit and flat rates of a bill impacts how much revenue a utility can generate within a given year. At the same time, utilities need to make sure their customers are able to afford the bills they are receiving or else the utility will lose this source of reliable customer revenue. Besides the revenue generated through the customer base, utilities receive funding from different levels of government to help finance a variety of projects. In 2014, over 95% of all governmental funding of water and wastewater utilities came from the local scale of city governments and municipality districts (National Academy of Public Administration, 2017). This can be a concern due to the limited amount of resources local governments have and the current estimated cost of replacing aging water and wastewater infrastructure in the Unities States being at over $1 trillion (American Society of Civil Engineers, 2017).

To help address the costs of aging infrastructure, the Drinking Water State Revolving Fund program was created as a way to lower the “costs of financing long-term investments or [provide] access to broader capital markets to secure financing that may not currently be available” (National Academy of Pubic Administration, 2017). The ability to use this type of funding can be limited though by not meeting all qualifications; such as being labeled a high cost system. Without this label, a city reduces or loses its ability to “establish an appropriate [combined sewer overflow] control implementation schedule” due to the lack of a high cost system label changing their financial capability status in application processes (USEPA, 1997). Following the creation of the Drinking Water State Revolving Fund, the Water Infrastructure Finance and Innovation Act in 2016 was passed to provide additional funding for projects over $20 million. With cities like Minneapolis and Saint Paul investing $330 million in separating their sewer and stormwater systems, financial resources like these policy-enacted funding and investment resources can help address growing concerns over the needs of aging and outdated infrastructure (Metropolitan Council, 2018).

From cities facing the burden of finding funding on a local scale for large infrastructure projects to public utility customers seeing the rate of water increase over the years, the price for providing and gaining access to water is being felt. Currently a number of articles and reports have been released over the concerns for customer affordability when it comes to water and wastewater services. These range from trying to provide different ways of identifying high cost systems, looking into barriers for customer assistance programs, and analyzing current policies addressing water use in urban environments (Mumm & Ciaccia, 2017, Mehan III & Gansler, 2017, & Easter, 2011). There has been little research on the link between affordability and the investments in water-related infrastructure. This paper examines different high cost system identification approaches and the relationship between these systems and the connection to cities that are addressing the financial needs of combined sewer overflow infrastructure.

Combined Sewer Overflow Systems

Introduced in 1855, one of the initial ways of managing large volumes of wastewater within urban environments was to install large underground pipe systems known as combined sewer overflow systems. "Hailed as vast improvements over urban cesspool ditches that ran along city streets," large metropolitan areas such as Chicago, New York, and Philadelphia adapted the technology to direct their wastewater and other sewage away from heavily populated areas and through the pipe systems where it would be dumped directly into local waterways (Tibbetts, 2005). The technology was later adapted to have the large underground pipes direct wastewater to treatment facilities to undergo purification, set under the Federal Water Pollution Control Act of 1948, before being released back into local waterways (USEPA, 1997). This was a very effective form of wastewater management for several decades because the pipes were large enough to handle to level of wastewater and stormwater during large rain events without dealing with overflow issues.

Combined sewer overflow systems have built in outfall pipes to quickly release excess wastewater directly into local waterways in the case of the system being overfilled to prevent back up into homes and businesses. “These overflows contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris” which can cause major environmental and health impacts (USEPA, 2017). Due to a wide variety of factors, including population growth of urban environments and increased construction of non-pervious surfaces, these systems started to experience more and more overflow events. To address these point source pollution events, the EPA implemented their Combined Sewer Overflow Control Policy in 1994 to implemented several controlling regulations to reduce the number of overflow events a city’s system could have in one year (Perciasepe, 1995). These regulations were required to be implemented by 1997 and have seen updates in policies in 1998, 1999 and 2014 (USEPA, 2017).

Cities have taken a wide variety of approaches to comply with these regulations. Some cities, such as Seattle, have raised water rates and gained additional funding to expand the diameter of their combined sewer overflow system in order to comply with limited overflow events (King County Wastewater Treatment Division, 2018). Others like Minneapolis and St Paul have invested in separating their sanitary and stormwater systems and created a regional program with surrounding communities to address and reduce “inflow and infiltration of stormwater and groundwater into wastewater pipes” (Metropolitan Council, 2018). Finally, large metropolitan cities like Chicago and New York City have added additional small-scale approaches on top of a wide breath of other projects; including large financially intensive infrastructure projects to partially separate and expand their systems to address these issues. These small-scale approaches include “Rain Blockers” which close off storm drains to turn local streets into “temporary reservoirs for 3-4 hours” until the pipes can once again handle the amount of stormwater left above ground or installing green stormwater infrastructure to manage and reduce the amount entering the systems (City of Chicago Department of Water Management, 2019, & Lehner, 2012).

Whether a city addresses complying with overflow regulations through one approach or many, the scale at which they need it to happen is extremely large and comes with increasing costs. During the initial stages of the EPA addressing pollution concerns over combined sewer over systems, they released the 1997 Combined Sewer Overflows – Guidance for Financial Capability Assessment and Schedule Development (1997 Guidelines). The purpose of this document was to “provide a planning tool for evaluating the financial resources a permittee has available to implement [combined sewer overflow] controls … [and] to assist the permittee, EPA and state [National Pollution Discharge Elimination System] authorities in cooperatively developing [combined sewer overflow] control implementation schedules (National Academy of Public Administration, 2017).”

To evaluate the financial resources of a city with a combined sewer overflow system, a wide variety of factors are considered, including the total annual waste water and combined sewer overflow control costs, debt the utility is facing, unemployment, median household income, property tax, use impairment of the infrastructure, grant/loan availability, rate structure, and the number of overflow sensitive areas (USEPA, 1997). These factors are then turned into the Residential Indicator (the 4% criteria the EPA uses to identify high cost systems for both water and wastewater) and the Financial Capability Indicator which the EPA and National Pollution Discharge Elimination System authorities use to negotiate “reasonable and effective schedules for implementation of” combined sewer overflow controls, identify site specific implementation for water quality standards due to local weather impacts, and qualification under the Construction Grant Program; later replaced by the Drinking Water State Revolving Fund (USEPA, 1997, & National Academy of Public Administration, 2017).

Since the initial release of the 1997 Guidelines, the EPA has issued a number of control policies, reports and memorandums trying to address the issue of communities dealing with affordability concerns due to the number of overflow events in cities still exceeding regulations (USEPA, 2017). These documents range from the EPA Environmental Financial Advisory Board commenting on the original 1997 Guidelines document in 2007 to the 2014 Financial Capability Assessment Framework for Municipal Clean Water Act Requirements. Faced with these financial concerns, the EPA's Water Infrastructure and Resiliency Finance Center stated that "many communities are experiencing significant financial hardships establishing adequate revenue streams necessary to finance projects and activities to maintain and upgrade their water infrastructure and meet their Clean Water Act and Safe Drinking Water Act obligations. While communities meet affordability tests for high cost systems at the community level, many low-income households within that community face tremendous challenges (Environmental Financial Advisory Board, 2016). These affordability concerns matched with financial constraints pose risks of communities dealing with high cost systems.

High Cost Systems and Indicator Approaches

With utilities across the country facing infrastructure costs of over $88 billion in combined sewer overflow systems alone, the risks of these costs being bore by customers has increased (National Academy of Public Administration, 2017). This concern comes from the fact that compared to other forms of infrastructure, local spending on water infrastructure can be over 95% of the funding sources. With many families facing affordability concerns due to increases in utility bills, the identification of high cost systems does not always accurately reflect these changes. The identification measurement of high cost systems, known as the Residential Indicator through the EPA, has remained constant since its initial formation through the 1997 Guidelines. Based on this approach, a community's average cost of water and wastewater service within a municipality's district is measured as a percentage of the median household income within the city limits. If this value is greater than 4.0 or 4.5% for combined water and wastewater services, the system is considered a high cost system (USEPA, 1997). This is important to note because the 1997 Guidelines state that cities "that have a low Residential Indicator…are unlikely to result in longer implementation schedules" and should forgo continuing the second phase of the application process (USEPA, 1997).

Due to the lack of change or review of the Residential indicator over the years, a number of papers have been published bringing attention to alternative high cost system indicators which account for variables such as the difference in average versus essential water use, median versus low household income, essential costs of living, and unemployment rates. Additionally, the National Academy of Public Administration (2017) was commissioned by the EPA to "conduct an independent study to create a definition of, and framework for, community affordability of clean water." From these articles and other publications, a variety of indicators have been presented to address high cost systems; these include but are not limited to: the Weighted Average Residential Index proposed by Jason Mumm, the Affordability Ratio by Manuel Teodoro, having the costs of service represented in hours of minimum wage by Manuel Teodoro, and using Census-defined income categories proposed by the United States Conference of Mayors and American Water Works Association (Mumm and Ciaccia, 2017, National Academy of Public Administration, 2017, Teodoro, 2018, & The United States Conference of Mayors et al., 2013).

The purpose of this research is to evaluate the links between water affordability and investments cities have made in developing combined sewer overflow systems. In particular, my research aims to address two questions:

1. How does the use of alternative affordability indicators affect the classification of metropolitan areas as high cost systems?
2. Are cities with combined sewer overflow systems more likely to be classified as high cost systems?

These two questions help to address the concerns over customer affordability and the struggle public utilities face with financing projects to comply with combined sewer overflow regulations. To test this, three different high cost system indicators will be used. The first indicator is the original EPA 1997 Framework which uses the Residential Indicator to identify a high cost system by a city's median household income. The second indicator is a modified approach to the Affordability Ratio presented by Manuel Teodoro and the final indicator is the Minimum Wage Indicator also proposed by Manuel Teodoro. From there, I the classify cities within the study as having either a combined sewer overflow or a separated system. This variable will be categorized based off whether cities qualify as high cost systems under the indicators mentioned previously to identify the portion of combined sewer overflow systems also being located within high cost systems.

Methods

I evaluated the links between affordability and combined sewer overflow systems in the thirty-five most populous metropolitan areas in the United States based on 2015 data. I collected data on the following variables for each city: the base rate, water rate, wastewater rate, presence of a combined sewer overflow system in the city, minimum wage (state minimum wage but used city minimum wage when different), city median household income, and lower 20th percentile median household income. A city was marked as having a combined system if they have a full combined sewer overflow system or if they have a partially separated and partially combined system. Half of the water and wastewater rates were derived from the American Water Works Association 2016 Water and Wastewater Rate Survey, and the remaining cities which were not included had the rates data collected through city government websites, public notice announcements of changes of rates, rate study documents, and phone calls to local public utilities and town hall offices (American Water Works Association, & Raftelis Financial Consultants, Inc, 2017).

To calculate the monthly water bills for each city, I assumed a 30-day month bill, a 2.5-person household (based on 2016 average household size), 100 gallons per capita per day usage, the same number of units of usage for both water and wastewater consumption, and all rates are for a single residential family household with a 5/8-inch meter in October 2016 (Statista, 2019, & United States Geologic Survey, 2019). I used October water rates to account for any rate changes for the new fiscal year of billing as well as avoiding any increased rate prices during the summer watering season. With these assumptions, each monthly bill was calculated for either 7,500 gallons or 1000 cubic feet for both water and wastewater; depending on which units the utility would use for their rate system. Additionally, when a tiered system had one tier with 5,000 gallons to 7,000 and another of 8,000 gallon and up, the lower tier was used; but when a tiered system had one tier with 5,001-7,000 and another from 7,001 to 9,000, the higher tiered was used to finish the remaining gallons of usage.

To estimate the EPA Residential Indicator, I multiplied the monthly bill by 12 months to create an annual water and wastewater bill. This was divided by the median household income variable to calculate the percentage of income used to afford water and wastewater annually. This value was then compared to the 4.0% indicator of a combined water and wastewater bill to identify high cost systems. This process was repeated for the modified Affordability Ratio Indicator but used the lower 20th percentile median household income instead of a city's median household income. The Minimum Wage Indicator was calculated by dividing the monthly bill by the city's minimum wage rate and comparing it to the criteria of a high cost system being 8.0 hours or higher in hours worked at minimum wage within a given month (Teodoro, 2018).

During this process, limitations are acknowledged when analyzing the results of combined sewer overflow systems having high cost systems. The City of Chicago has a unique situation in their approach to pricing their water system. Currently, the city has two separate pricing systems: a rate system that is used in this analysis for metered residential homes and a flat rate billing cycle for nonmetered residential homes. To increase the number of metered homes, the city initiated its MeterSave program where any family will "receive a 7-year guarantee that their water charges won't go higher than what they would have been if the meter had not been installed (City of Chicago Department of Water Management, 2018)." This can influence the ability of the city to properly price their water due to restrictions faced by the utility. Since Chicago is a combined sewer overflow system, this could impact the correlation between these types of systems and identifying the significance of this relationship. Additionally, the lack of data available for Boston, which is also a combined sewer overflow system, could influence these relationships as well. Even with multiple attempts of reaching out to Boston, no rate data were collected. Both cities are included in the figures provided in the analysis section but Boston is later removed from the data used for t-tests. I did not look into data on infrastructure age, population size and types of funding programs specific public utilities might have access to even though these variables can have an influence on a city being a high cost system.

Analysis

I combined utility rate data and socioeconomic data into a database in order to calculate the three high cost price indicators. I graphed and compared this to the specific criteria for each indicator to identify whether a city qualifies as a high cost system; these results can be seen in Figures 1, 2, and 3. In each of the figures, all 35 cities are labeled on the vertical axis. The horizontal axis is in percentage of median household income spent on an annual water bill for the Residential Indicator and modified Affordability Ratio Indicator while the Minimum Wage Indicator has the horizontal axis as the number of hours worked to afford a monthly water bill. The criteria for each indicator are identified through a black line running along either the 4% mark or the 8-hour mark on the horizontal axis. In addition, the figures show which cities have combined sewer overflow systems (including partial systems) and those which have separated sewer systems. For the Residential Indicator, 4 cities out of the 35 analyzed were identified as having high cost systems. All 4 were cities contained combined sewer overflow systems and this accounted for 23% of all the combined sewer overflow systems within this analysis. With this being the indicator used by the EPA for the Drinking Water State Revolving Fund, very few would meet this part of the qualification process.

Using the Affordability Ratio Indicator, 24 out of the 35 cities were identified as having high cost systems. From these cities, 14 contained combined sewer overflow systems and accounted for 82% of all combined sewer overflow system being considered high cost systems within my analysis. These numbers are very similar to those derived from Minimum Wage Indicator which identified 25 out of 35 cities as high cost systems and the same number of cities having combined sewer overflow systems. With both indicators identifying 14 cities with combined sewer overflow systems, a higher number of cities would meet the high cost system indicator under the Drinking Water State Revolving Fund. A switch to a different indicator could be the difference between cities gaining access to new financial sources or creating a more feasible schedule for infrastructure changes that address concerns over the number of overflow events a city sees each year.

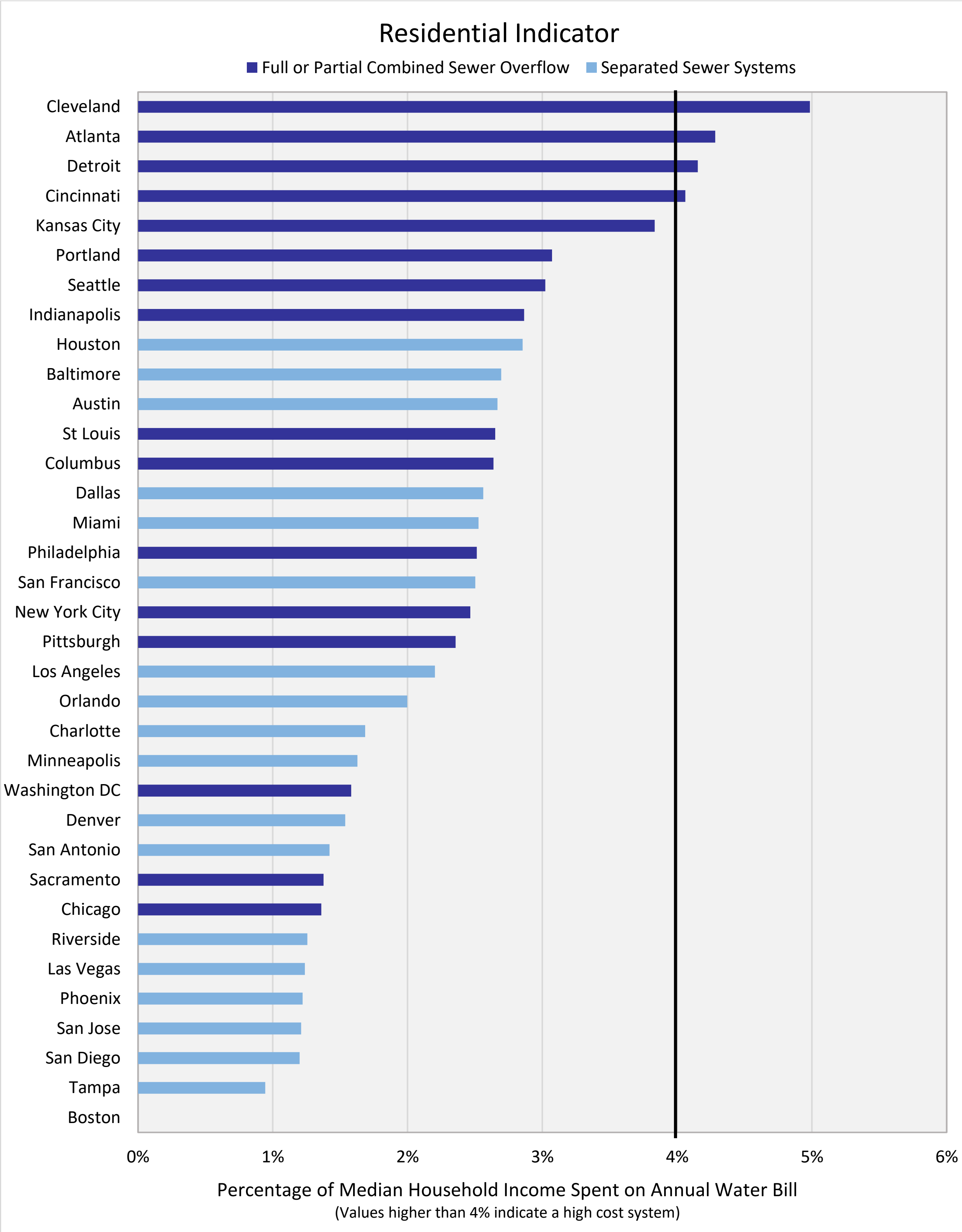

Figure 1 High Cost Systems Identified Under the Residential Indicator (black line indicates 4.0% criteria)

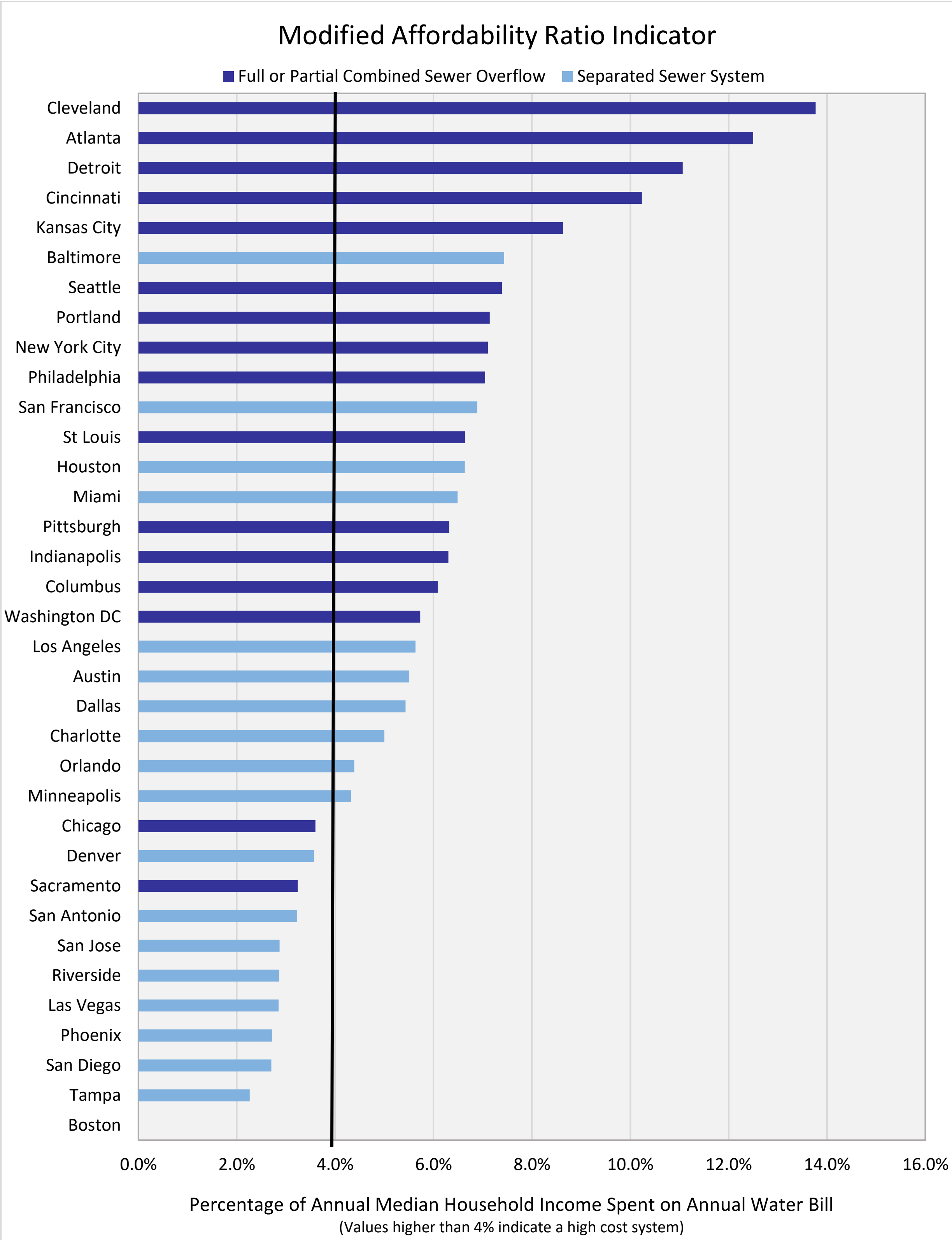

Figure 2 High Cost Systems Identified Under the Modified Affordability Ratio Indicator (black line indicates 4.0% criteria)

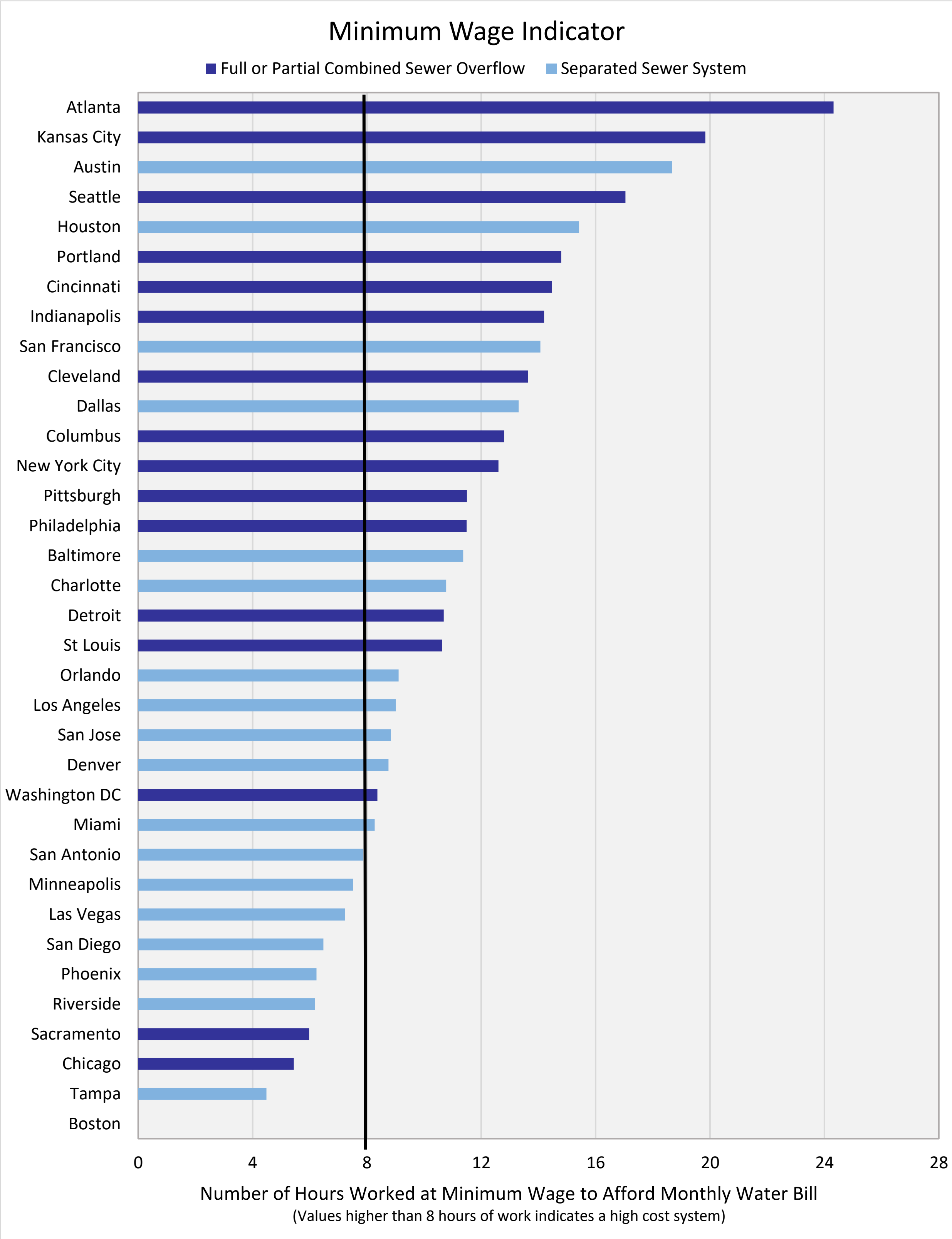

Figure 3 High Cost Systems Identified Under the Minimum Wage Indicator (black line indicates 8.0-hour criteria)

The data for each of the indicators were run through a two-sample t-test using STATA to identify whether there is a significant relationship between cities having combined sewer overflow systems and qualifying as a high cost system. The Residential Indicator, the modified Affordability Ratio Indicator and the Minimum Wage Indicator were all the dependent variables for their respective t-tests with the Residential Indicator and the modified Affordability Ratio Indicator in values of percentage of median household income spent on an annual water and wastewater bill and the Minimum Wage Indicator in values of number of hours worked at minimum wage to affordable a monthly water and wastewater bill. The dummy variable identifying whether a city has a combined sewer overflow system was used as the independent variable for each t-test.

From these tests, a statistically significant relationship at a 95% confidence level can be determined with a p value of 0.05 or lower. Any significance between the variables is viewed as a correlation rather than a causation of the combined sewer overflow systems leading to cities having high cost systems. From these t-tests, the results of can be seen in Table 1 where the p value for each of the variables and descriptive statistics are listed and the outputs of the t-tests can be found in Appendix C. All three indicator variables had a significant relationship with combined sewer overflow systems but the Residential Indicator and the modified Affordability Ratio Indicator have a stronger relationship with combined sewer overflow systems than the Minimum Wage Indicators. Even though these variables are significant, it is important to acknowledge that the size of the sample was small due to the nature of the analysis and the relationships might change if more cities are added to the dataset. This is important to take into consideration because Boston was removed from the dataset due to lack of available data.

STATA T-Test Results (Number of Observations: 34 Cities)		
Residential Indicator	Modified Affordability Ratio Indicator	Minimum Wage Indicator
P Value: *0.0009*	P Value: *0.0004*	P Value: *0.0281*
Mean Value*: 2.37%*	Mean Value*: 5.99%*	Mean Value*: 11.22 hours*
Standard Deviation: *1.02%*	Standard Deviation: 2.82*%*	Standard Deviation: 4.49 hours
95% Confidence Interval: *2.01-2.73%*	95% Confidence Interval: *5.00-6.97%*	95% Confidence Interval: *9.65-12.78 hours*

Table 1 Results of T Test Where the P Value is Considered Significance if it is 0.05 or Lower

Discussion

This research helps to add to the body of literature on the use of different indicators for high cost system variables and the connection of these systems to combined sewer overflow systems. When cities apply for funding and plan approval to address their combined sewer overflow systems, being a high cost system impacts qualifying for extended deadlines and financial resources through the 1997 Guidelines application process (USEPA, 1997). If the current form of indication is not properly representing which cities are facing a high cost system, they cannot properly address the variety of issues they face when trying to either separate their systems, expand the pipelines or address concerns through alternative approaches such as green stormwater infrastructure.

Alternative Affordability Indicators

Being able to properly identify high cost price systems plays a role in influencing decisions utility companies can take in future required action like increasing rate structures or investing in infrastructure improvement projects; but it also shines a light on customer affordability. The use of the alternative approaches within this analysis show the need for future research and increased use of a variety of variables that address the difference in average versus essential water use, median versus low household income, essential costs of living, and unemployment rates. Through the current application of the Residential Indicator by the EPA, these important socioeconomic variables are not being accounted for and can be painting a different picture than what is actually happening. By using only median household income, the impacts on low income households can be overlooked; especially if there is a large proportion of high-income families within the service area. Incorporating variables that reflect the impacts of a rate system on the families who can feel it the most can quickly change the status of a city previously not considered a high cost system into one that easily meets the qualifications.

Looking at the differences between where cities fall within the three indictors being analyzed can help provide a better picture on the types of approaches the EPA can use in their future decisions towards high cost systems and funding projects for combined sewer overflow systems. Detroit and Cleveland are good examples of this. When looking at the Residential Indicator and the modified Affordability Ratio Indicator, they are both near the top of the list and qualify as high cost systems but the story is a little different when you look at the Minimum Wage Indicator. Two cities that were in the top three for high cost systems when looking at an annual water bill move down closer to the middle of the list when looking at a monthly bill and minimum wage. The opposite is true for cities like San Jose and Denver. When looking at the annual bill, these cities don't qualify under the criteria as a high cost system but when you look closer in the month to month, they rise up the chart and actually turn into cities with a high cost system. This can mean that even though families in these regions look like they are able to afford their water and wastewater bills annually, it might be a different story where they are struggling in certain months over others depending on how many hours a month they work if they are currently at minimum wage. This difference in variable usage when choosing an alternative approach to identifying high cost price systems greatly impacts what types of results play out. A possible consideration for changes in the EPA's current process would be looking at both the annual and monthly bills of systems and picking an approach or approaches that best address both types of customer affordability concerns.

Combined Sewer Overflow Systems

The different approaches in this analysis highlight the role combined sewer overflow systems play in financial decisions public utilities can make. There is a noticeable relationship present through the use of the alternative indicators where 82% of all combined sewer overflow systems qualify as high cost price systems. This is also seen when looking at the resulting P values of Table 1 where a significant correlation is present between cities having combined sewer overflow systems and having a higher percentage of median household income spent on an annual water and wastewater bill or a higher number of hours worked at minimum wage to afford a monthly water and wastewater bill. Even with these results, there is not much research on the impact combined sewer overflow systems can have on communities. Further research into the correlation between cities having this type of infrastructure and being affordable for their customer base can be used to provide additional information on future steps that need to be taken. These steps can include creating and providing additional educational materials for cities with this infrastructure on the impacts it can have on affordability or taking into consideration combined sewer overflow system in loan application processes to help reduce the financial burden on customers when public utilities are investing in new or updated infrastructure projects.

To address concerns over high cost systems and customer affordability, many utilities implement customer assistance programs for their communities. These programs are ways for utilities to help their low income and struggling households afford their water and wastewater bill each month. These different approaches can range from bill discounts, flexible terms, lifeline rates, temporary assistance and water efficiency initiatives (Mehan III and Gansler, 2017). Further research is needed that investigates barriers that cities face in adopting these interventions, including current legislative restrictions and financial structures. Through identification, local governments and public utilities can take steps to remove or work around their barriers in an effort to better service their most impacted families.

Conclusion

Whether it be local utilities coming together to have a conversation on regional affordability or it is the EPA trying to understand the concerns across the country by commissioning reports on the subject, water affordability is a conversation many are starting to have. Finding the best approach to identifying these concerns can help open doors for utilities facing financial constraints when it comes to addressing combined sewer overflow systems. At the same time, having this conversation requires bringing up concerns over customer affordability and the struggles families are facing with paying their water and wastewater bills; whether it be annually or just certain months. The information gained from this study helps to show that the current criteria for identifying high cost systems through the EPA is not the best approach when it comes to actually understanding the financial situation of cities. Bringing in more variables that address the concerns over low income households and looking at both annual and monthly water and wastewater bills can provide a more accurate picture on what cities quality as high cost systems. In addition, gaining a better understanding over how combined sewer overflow systems influence customer affordability will help create a clearer image on high cost systems. Further research into alternative high cost system indicator approaches and the best variables to use for properly representing struggling households can help identify the best qualification criteria for the Drinking Water State Revolving Fund and other financial programs for addressing combined sewer overflow systems and future water infrastructure investments. With the current status of aging infrastructure in America, it is important to replace what is needed while at the same time making sure the financial burden isn't placed on customers; especially those in low income households. There is a lot of opportunity for understanding the struggles cities are facing with water affordability but without proper identification of financial constraints within these cities, progress and investment cannot be made at the scale that is needed.

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Appendix A

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Appendix B

Data Used for Calculations of High Cost System Indicators

City	Combined Sewer Overflow System	Median Household Income	Lower 20th Percentile Median Household Income	Calculated Water and Wastewater Monthly Bill	Minimum Wage
Atlanta	Yes	$49,398	$16,927	$176.32	$7.25
Austin	No	$60,939	$29,502	$135.40	$7.25
Baltimore	No	$44,262	$16,040	$99.42	$8.75
Boston	Yes	$58,516	$17,734	N/A	$10.00
Charlotte	No	$55,599	$18,751	$78.10	$7.25
Chicago	Yes	$50,434	$19,048	$57.15	$10.50
Cincinnati	Yes	$34,629	$13,738	$117.20	$8.10
Cleveland	Yes	$26,583	$9,625	$110.43	$8.10
Columbus	Yes	$47,156	$20,454	$103.66	$8.10
Dallas	No	$45,215	$21,312	$96.48	$7.25
Denver	No	$56,258	$24,182	$72.04	$8.23
Detroit	Yes	$26,249	$9,852	$90.83	$8.50
Houston	No	$47,010	$20,219	$111.78	$7.25
Indianapolis	Yes	$43,101	$19,598	$102.89	$7.25
Kansas City	Yes	$47,489	$21,096	$151.71	$7.65
Las Vegas	No	$50,882	$22,112	$52.45	$7.25
Los Angeles	No	$51,538	$20,152	$94.62	$10.50
Miami	No	$31,642	$12,311	$66.59	$8.05
Minneapolis	No	$52,622	$19,829	$71.40	$9.50
New York City	Yes	$55,191	$19,144	$113.40	$9.00
Orlando	No	$44,007	$20,051	$73.28	$8.05
Philadelphia	Yes	$39,770	$14,185	$83.30	$7.25
Phoenix	No	$49,328	$22,177	$50.20	$8.05
Pittsburgh	Yes	$42,450	$15,827	$83.33	$7.25
Portland	Yes	$58,423	$25,113	$149.51	$10.10
Riverside	No	$58,979	$25,876	$61.77	$10.00
Sacramento	Yes	$52,071	$22,129	$59.74	$10.00
San Antonio	No	$48,183	$21,195	$57.07	$7.25
San Diego	No	$68,117	$30,228	$68.04	$10.50
San Francisco	No	$87,701	$31,840	$182.85	$13.00
San Jose	No	$90,303	$38,087	$91.03	$10.30
Seattle	Yes	$74,458	$30,429	$187.45	$11.00
St Louis	Yes	$36,809	$14,690	$81.28	$7.65
Tampa	No	$45,874	$19,144	$36.10	$8.05
Washington, DC	Yes	$72,935	$20,152	$96.18	$11.50

Appendix C

STATA Two Sample T-Test Output

Table 2 Variables Used for Two-Sample T-Test

Variables Found Within Stata Outputs	
RI	Residential Indicator
ARI	Affordability Ration Indicator
MWI	Minimum Wage Indicator
CSO	Dummy Variable Identifying Cities with Combined Sewer Overflow Systems

```
. ttest RI, by(CSO)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       0 |      18    .0185243    .0015185    .0064425    .0153205    .0217281
       1 |      16    .0295084    .0026807     .010723    .0237945    .0352223
---------+--------------------------------------------------------------------
combined |      34    .0236933    .0017541    .0102282    .0201245     .027262
---------+--------------------------------------------------------------------
    diff |           -.0109841    .0029943               -.0170834   -.0048849
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t =  -3.6683
Ho: diff = 0                                     degrees of freedom =       32

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0004         Pr(|T| > |t|) = 0.0009          Pr(T > t) = 0.9996
```

Figure 4 Two-Sample T-Test for Residential Indicator Where P-Value of 0.05 or Lower is Considered Significant with a 95% Confidence Intervolve

```
. ttest ARI, by(CSO)

Two-sample t test with equal variances

   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       0 |      18    .0448881    .0039726    .0168541    .0365067    .0532694
       1 |      16    .0767473    .0072986    .0291943    .0611908    .0923038
---------+--------------------------------------------------------------------
combined |      34    .0598807    .0048334     .028183    .0500471    .0697142
---------+--------------------------------------------------------------------
    diff |           -.0318592    .0080611               -.0482791   -.0154394
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t =  -3.9522
Ho: diff = 0                                     degrees of freedom =       32

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0002         Pr(|T| > |t|) = 0.0004          Pr(T > t) = 0.9998
```

Figure 5 Two-Sample T-Test for the Modified Affordability Ratio Indicator Where P-Value of 0.05 or Lower is Considered Significant with a 95% Confidence Intervolve

```
. ttest MWI, by(CSO)

Two-sample t test with equal variances

   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       0 |      18    9.643264    .8667218    3.677189    7.814641    11.47189
       1 |      16    12.98509    1.193883    4.775532    10.44039    15.52979
---------+--------------------------------------------------------------------
combined |      34    11.21589     .770763    4.494282     9.64776    12.78402
---------+--------------------------------------------------------------------
    diff |           -3.341829     1.45261               -6.300699   -.3829586
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t =  -2.3006
Ho: diff = 0                                     degrees of freedom =       32

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0140         Pr(|T| > |t|) = 0.0281          Pr(T > t) = 0.9860
```

Figure 6 Two-Sample T-Test for Minimum Wage Indicator Where P-Value of 0.05 or Lower is Considered Significant with a 95% Confidence Intervolve